IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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The following is a marked-up version of the amended specification for the 312 Amendment after Allowance, showing the changes to ths specification.

IN THE SPECIFICATION:

On page 2, under the "Field of the Invention"

Field of the Invention

The present invention relates to a combustion monitoring system in general, and in particular to a system for monitoring conditions in the combustion system of a gas turbine.

On Page 5, first paragraph,

Endoscopes may also ~~often~~ be used within industry to visually inspect flames, and their interaction between the furnace load. They are generally complicated and expensive pieces of equipment that require careful maintenance. To be introduced into very high temperature furnaces or burners, they require external cooling and flushing means: high-pressure compressed air and water are the most common cooling fluids. When compressed air is used, uncontrolled amounts of air are introduced in the furnace and may contribute to the formation of NO_x. Water jackets are subject to corrosion when the furnace atmosphere contains condensable vapors.

On page 6, first paragraph,

Continuous monitoring carbon monoxide of the flue gas, for example in so-called post combustion control of a burner assembly, provides another means of controlling the combustion. This involves the use of a sophisticated exhaust gas sampling system, with separation of the particulate matter and of the water vapor. Although very efficient, these techniques are not always economically justified. Also, the light emissions observed from the flame ~~is~~ are one of the most useful systems for providing information on the chemical, as well as physical processes, as noted hereinabove, that take place in the combustion process. For example, Cusack et al., U.S. Patent No 6,071,114 uses a combination of ultraviolet, visible and infrared measurements to characterized the flame to determine relative levels of some chemical

constituents. While monitoring the flame light emission can be easily performed in well controlled environments typically found in laboratories, implementing flame light emission monitoring on industrial burners used in large combustion units is quite difficult in practice, resulting in a number of problems. First, clear optical access is necessary which requires positioning of a viewing port in a strategic location with respect to the flame for collecting the flame light emission. Second, the environment is difficult because of excessive heat being produced by the burner. Typically the high temperature-operating environment of the burners necessitates the need for water or gas cooled probes for use either in or near the burner. Finally, the environment may be dusty which is not favorable for the use of optical equipment except with special precautions, such as gas purging over the optical components.

On page 6, second paragraph continuing onto page 7,

Control of the combustion process at the burner can be performed by metering the flows of fuel and oxidant, through appropriately regulated valves (electrically or pneumatically driven) that controlled by a programmable controller (PC). The ratio of oxidant to fuel flow is predetermined using the chemical composition of the natural gas and of the oxidant. To be effective, the flow measurements for the fuel and oxidant must be very accurate and readjusted on a regular basis. Typically this situation often leads the operator to use a large excess of air to avoid the formation of CO. Further, typical combustion control strategies do not account for the air intakes that naturally occur in industrial burners that bring in unaccounted quantities of oxidant into the combustion zone, nor does this control scheme account for the variation of the air intakes caused by pressure changes in the burner. Another drawback is that the response time of the feed-forward regulation loop is generally slow, and ~~can not~~ <u>cannot</u> account for cyclic variations of oxidant supply pressure and composition that occur when the oxidant is not pure oxygen. Other drawbacks of combustion control strategy result from variations due to fuel composition and pressure.

On page 10, paragraph 4,

Fuel and an oxidizer are provided to the fuel nozzle at separate rates. The amount of oxidizer fuel supplied is slightly greater than the ~~stoicicometric~~ <u>stoichiometric</u> required. The fuel

and oxidizer are ignited thereby initiating the combustion process, which produces a flame. One of the products of the combustion process is hydrocarbon ions~~;~~.

In the "Brief Description of the Drawings"

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of the present invention situated on the center-body of a typical fuel nozzle of a lean premix combustion system;

Figure 2 is a cross-section illustration of the present invention; ~~and~~

Figure 3 is a sectional view of the present invention while situated in a typical fuel nozzle of a lean premix combustion system;

Figure 4a and 4b are typical control/ detection circuits;

Figure 5 is a graph of voltage vs. current for a constant bulk velocity;

Figure 6a is a graph of OH^- measurement vs. equivalence ratios;

Figure 68b is a graph of average current with Vbias of 100 VDC vs. equivalence ratios;

Figure 7a is a graph of OH^- measurement vs. fuel flow rates;

Figure 7b is a graph of average current with Vbias of 100 VDC vs. equivalence ratios;

Figure 8a is a graph of OH^- measurement vs. equivalence ratios; and

Figure 8b is a graph of average current with Vbias of 100 VDC vs. equivalence ratios.

On page 13 beginning at line 12 and continuing to page 16

The swirl vanes **24** serve to ~~enhance~~ provide for thorough burning of the fuel/air mixture within the combustion zone **14** by ensuring that the fuel/air mixture will be well blended, thereby producing the richest possible combustion.

In most cases, air, as the oxidant and gaseous fuel are mixed in the pre-mixer section located in the fuel nozzle **10**. The fuel/air mixture ~~**36**~~**37** is introduced into the fuel nozzle ~~**16**~~**10** through inlet **26**. The fuel/air mixture ~~**36**~~**37** is then injected into the combustion zone **14** through nozzle outlet ports **28**. An ignition source **38** ignites the fuel/air mixture thereby initiating the combustion process **40** or flame.

The structure of the combustion first electrode **18** of the present invention and the associated electrode assembly, shown generally as **42** in FIGURE 2. The assembly **42** is

made up of two main components, a combustion first electrode **18**, also referred to as a guard electrode G for other uses, and a first insulator **44**. The flashback first electrode **22**, shown here, while not of primary importance for this invention, has utility for sensing other combustion conditions. The first combustion electrode **18** is made of an electrically conducting material, such as metal that is capable of withstanding the normal operating temperatures produced in a combustion system. The material should also be able to withstand the high temperatures presented during normal combustion and flashback conditions.

The ~~sensor body~~ first insulator **44** is made of a non-conducting but rugged material, such as an engineered thermoplastic or ceramic, that is also able to withstand both the normal operating temperatures produced during combustion in a gas turbine system as well as the high temperatures presented during a flashback condition. The sensor body **44** preferably has a circular shape with a smooth surface. The first combustion electrode **18** and the flashback first electrode **46** are securely seated in the center body **30.** These electrodes are electrically and physical isolation from one another, but in such manner that a significant portion of the face of the combustion first electrode **18** and the flashback first electrode **22** are exposed. The flashback first electrode **22** is electrically insulated from the rest of the center body **30** by insulator **48**. The combustion first electrode **18** is electrically charged by coaxial cable **50**. The flashback first electrode **22** is electrically ~~charger~~ charged by coaxial cable **52**.

The first combustion electrode **18** is securely fastened to the nozzle center body **30** within the fuel nozzle **16** at a location downstream from the pre-mixer section of the gas combustion system, but in close proximity to the combustion chamber **12**, as shown in Figs. 1 and 2. The ~~combustion~~ first combustion electrode **18** is located on the nozzle center body **30** so as to expose the first combustion electrode ~~**34**~~ 18 to the combustion process **40** which takes place within the combustion zone **14**. FIGURE 3 provides a detailed view the fuel nozzle **10**, combustion chamber **12** and combustion sensor **16**, so as to illustrate the current between the first **18** and second combustion electrodes **20**. One potential current path **54** extends between the first combustion electrode **18** and the second the second combustion electrode **20** (combustion ground). At least a portion of the combustion process (flame) **40** is between the two electrodes. A second electrical field **56** extends between the flashback first

electrode **22** and the flashback ground **58**. The flashback ground **58** may be incorporated in the nozzle wall **60**, applied as a coating to the inner wall **62** thereof, or maintained at a short distance therefrom ~~**58**~~. The fuel nozzle **10**, swirl vanes **24**, fuel/air inlet **26**, and the combustion zone outer wall **64** remain the same as shown and discussed with respect to FIGURE 1.

The combustion zone electric field **54**, extend between the first combustion electrode **18** and ~~the second~~ the second combustion electrode **20** (combustion ground) and ~~pass~~ passes through the combustion flame. The lines of electric field **54**, are produced and controlled by a detector circuit **62**, as shown in detail in Fig 4 and discussed herein later, which is ultimately responsible for the control and supervision of the electrodes **18** and **20**. A detector circuit **62** for each set of electrodes is connected between the electrode and ground by conductors **50** and **66** (For demonstration only one detector circuit is shown). The detector circuit includes a current sensing circuit couple to each of the first combustion electrode **18** and ~~the second~~ the second combustion electrode **20** (combustion ground). The detector circuit is also responsible for indicating a current that is proportional to the combustion product level within the combustion process (flame) **40**.

Each set of electrodes will have a separate detector circuit, with equal-potential bias voltage, so the current measured through each electrode is independent of the other. Examples of a typical control circuit for the monitoring of the combustion process are shown in Figures 4a and 4b. This circuit supplies a bias voltage to the electrode and measures the current conducted through the electrode. The remainder of the nozzle and combustion chamber are at reference ground potential in respect to the circuit shown in Figure 4. The electrometer configuration shown in Figure 4 provides a voltage output proportional to the amount of current conducted through the electrodes, which can be used to signal that a flashback condition has occurred. Other circuits may be used to interface to the flashback sensor electrodes, while maintaining the functionality of the flashback detection sensor.

In cooperation with the first combustion electrode 18 and ~~the second~~ the second combustion electrode **20** the detection circuit detects the level of combustion product within the combustion process (flame) **40**, occurring within ~~a in~~ the electric current **54**. Thereby, any change in the status of the electric fields **54**, indicating that a change has occurred in the

electric circuit is completed between the first combustion electrode **18**, and the second electrode **20**. The detector circuit may further comprise a current amplifying circuit and a processor. A microprocessor may be configured to indicate the level of hydrocarbon based on empirical data. The current generating subcircuit may provide either an alternating current (AC) or direct current (DC).

On page 16 in the first paragraph under "Experimental Tests"

The combustion sensor was installed in a low-pressure development combustion rig as shown in Fig. 1. The data discussed in the next section was collected using two combustion chamber configurations. The combustion configuration illustrated in Fig 6 ~~were~~ was constructed with two 1/4-in (316 stainless steel tubes with ceramic inserts) electrodes installed 180E apart inside the cylindrical, quartz combustion tube. The ~~tow~~ two electrodes were electrically isolated from the remaining conductive combustor surfaces and were connected to the current measurement circuit by stainless steel wires. This configuration is referred to as the isolated electrode configuration. The second configuration as shown in Figure 1 consists of a solid metal combustor tube, which was connected to the remaining conductive metal conductive metal surfaces (i.e., cumbustor ground, or earth). This configuration is referred to as the metal combustor configuration.